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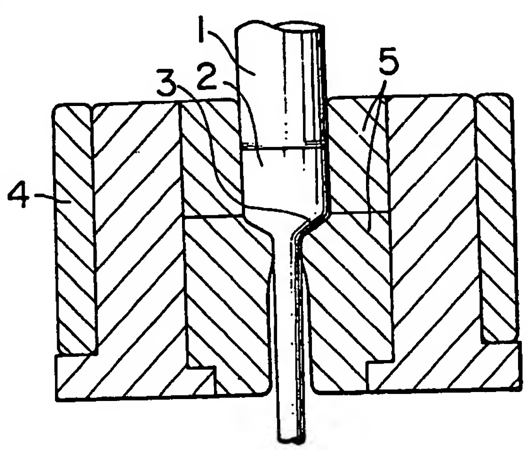
(54) Lubricant for metal forming and process for metal forming.

(57) A substantially water-free, liquid lubricant for metal forming, which comprises (a) a lubricating oil, and (b) at least one phosphoric acid monoester from the group represented by the general formula:

$$RO-\overset{\displaystyle O}{\overset{\|}{P}}-(OH)_2$$

wherein R is alkyl, alkylalkenyl or aryl, and optionally (c) at least one member of the group including fatty acids, fatty acid amides and metal soaps, can form a lubricating film with a good heat resistance and good lubricating properties by virtue of the heat generated by deformation and friction during the forming only by wetting the surface of a metallic workpiece (2) or a die (5) with the liquid lubricant, and can work effectively for prevention of galling. Parts or articles with a higher reduction of area and complicated shape can be readily formed. Furthermore, a film having a lubricating effect equivalent to that of the conventional phosphate coating film can be simply obtained with a great contribution to product cost reduction.



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LUBRICANT FOR METAL FORMING AND PROCESS FOR METAL FORMING

BACKGROUND OF THE INVENTION

This invention relates to a lubricant for metal forming, which can form a lubricating film on a metal surface by virtue of the heat generated by deformation or friction during the metal forming such as cold forming i.e. forming without heating of a metallic workpiece, etc., and also to a process for metal forming with said lubricant.

A lubricant for metal forming must have a satisfactory lubricating ability up to an elevated temperature caused by deformation, friction, etc. and also to increasing new surface area of a workpiece created by the metal formation. The lubricants so far proposed for this purpose are water-soluble or water-insoluble liquid lubricants containing mineral oil or synthetic oil or their mixture as the major component and further containing a semi-solid libricant such as metal soap, beef tallow, etc., a sulfur-based, chlorine-based, or phosphorus-based extreme pressure agent, or a solid lubricant such as graphite, molybdenum disulfide, etc. These lubricants can be used, without any problem, for the metal forming with low reduction of area, but in the case of high reduction of area which produces a higher temperature or a higher surface pressure, or in the case of forming products of complicated shapes,

their load-carrying capacity, heat resistance, etc. are not satisfactory, resulting in galling. For the lubrication for larger plastic deformation, or forming products of complicated shapes, it has been so far proposed to plate a workpiece surface with a soft metal, such as copper, etc., or to coat a workpiece surface with a plastic resin film. A phosphate coating process comprising a series of such steps as defatting-water washing-acid pickling-phosphating-water washing-neutralization treatment-metal soap lubrication treatment-heat drying of a workpiece is also well known.

These lubricating coating treatments all require a sufficient pretreatment and complicated coating steps, and thus require so many labors and costs and also have further problems of removing the coatings after the forming or of environmental pollution by the waste liquor liquid from the coating treatments after the forming.

Recently, lubricants containing phosphoric acid or its salts, boric acid or its salts, carbonates, nitrates, sulfates, or hydroxides of alkali metal, and laminar silicate, etc. have been proposed (Japanese Patent Application Kokai (Laid-open) No. 57-73089). However, since they consist of water-soluble glass powder of P_2O_5, B_2O_2 and M_2O (where M represents an alkali metal), and the laminar silicate, or their mixture and water, they fail to show lubrication at a low temperature forming (below about 300°C) such as cold

forming, and thus cannot be used in the cold forming.

Furthermore, an acidic lubricant for cold forming, which is prepared by reaction of a multivalent metal cation, orthophosphate, and alkyl alcohol or alkylaryl alcohol having 10 to 36 carbon atoms, and which has a water content of not more than 20% by weight has been proposed (Japanese Patent Publication Kokai (Laid-open) No. 47-15569), and liquid or paste lubricants further containing mineral oil, carboxylic acid, and alkylamine besides the said lubricant components, lubricants for cold forming, which comprises 30 to 94% by weight of a lubricant such as mineral oil, oleic acid, or oleylamine, 5 to 60% by weight of a reaction product of a multivalent metal cationic salt, polyphosphoric acid and an alcohol having 10 to 36 carbon atoms in a ratio of the metal cation : P_2O_5 : the alcohol = 1 : 3-60 : 14-150 by weight, and 0.5 to 10% by weight of water have been proposed (U.S. Patent No. 3,932,287). These lubricants show good results in drawing processing of pipes, etc., but fail to meet the requirements for forming steel workpieces with high reduction of area.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a substantially water-free, liquid lubricant for metal forming, which can have an excellent lubricating ability even under high reductions of area which produces a higher temperature and a higher pressure at the sliding interface

between a tool and a workpiece, and can give a distinguished formability during the cold forming.

Another object of the present invention is to provide a process for metal forming in a very simple manner in forming a lubricating film, using a substantially water-free, liquid lubricant for metal forming, which can keep an excellent lubricating ability even under high reductions of area which produces a higher temperature and a higher pressure, and can give a distinguished formability during the cold forming.

According to a first aspect of the present invention a lubricating film having a good heat resistance and a good lubricating ability is formed on the surface of a metallic workpiece by virtue of the heat generated by deformation, or friction during the metal forming only by wetting the surface of a metallic workpiece such as a steel workpiece, or the surface of a die with a substantially water-free, liquid lubricant for metal forming, which comprises a lubricating oil and at least one of phosphoric acid monoesters represented by the following general formula (1):

$$RO-\overset{\displaystyle O}{\overset{\|}{P}}-(OH)_2 \qquad (1)$$

wherein R is alkyl, alkylalkenyl or aryl.

According to a second aspect of the present invention, a lubricating film having a good heat resistance and a good lubricating ability is formed on the

surface of a metallic workpiece by virtue of the heat generated by deformation or friction during the metal forming only by wetting the surface of a metallic workpiece or the surface of a die with a substantially water-free, liquid lubricant for metal forming, which comprises a lubricating oil, at least one of said phosphoric acid esters represented by said general formula (1), and at least one of fatty acid, fatty acid amide, and metal soap.

The lubricating oil for use in the present invention is the ordinary, commercially available lubricating oil, including, for example, mineral oil, synthetic oil such as ester oil, ether oil, silicone oil and fluorinated oil, and their mixtures.

It is preferable to select the viscosity of the lubricating oil in view of desired reduction of area, method for supplying the lubricating oil to a lubricating surface, etc.

The phosphoric acid monoesters for use in the present invention include, for example, monomethyl phosphate, monoisopropyl phosphate, monobutyl phosphate, monoactyl phosphate, monoisodecyl phosphate, monododecyl phosphate, monotridecyl phosphate, monooctadecyl phosphate, monooleyl phosphate, monophenyl phosphate, etc. The phosphoric acid monoesters can be used in the form of solution or suspension or dispersion in said lubricating oil. In the case of dispersion, it is preferable to add an emulsifying agent thereto. Preferable emulsifying

agent includes polybutenylsuccinic acid imide obtained by reaction of polybutenylsuccinic acid anhydride with an amine or alcohol, copolymers of polybutenylsuccinic acid ester and polymethacrylate or polyolefin, etc.

By adding at least one of fatty acid, fatty acid amide and metal soap to the lubricating oil containing the phosphoric acid monoester, formation of a film of the phosphoric acid monoester can be promoted and the lubricating ability can be much improved, so that higher forming performance can be obtained.

The fatty acid and fatty acid amide for use in the present invention are natural fatty acids, synthetic fatty acids and fatty acid amide prepared by condensation reaction of fatty acid and amine, and include, for example, butanoic acid, pentanoic acid, hexanoic acid, octanoic acid, nonanoic acid, decanoic acid, undecanoic acid, dodecanoic acid, tetradecanoic acid, hexadecanoic acid, octadecanoic acid, cis-9-cis-12-octadecadienoic acid, cis-9-cis-12-cis-15-octadecatrienoic acid, 9-decenoic acid, cis-9-octadecenoic acid, heptanoic acid, and their amides, for example, hexanamide, butanamide, octanamide, nonanamide, decanetriamide, undecanamide, dodecanamide, tridecanamide, myristylamide, palmitylamide, stearylamide, oleylamide, linolamide, etc.

The metal soap for use in the present invention includes, for example, soap obtained by reaction of fatty acid having not more than 22 carbon atoms with a

metal such as an alkali metal or nickel.

In the case of a liquid lubricant according to the first aspect of the present invention which comprises (a) a lubricating oil and (b) a phosphoric acid monoester represented by the general formula (1), it is desirable to use 2 to 30 parts by weight of the phosphoric acid monoester per 100 parts by weight of the lubricating oil. Below 2 parts by weight of the phosphoric acid monoester, formation of a lubricating film is deteriorated and a sufficient formability cannot be obtained, so that galling may sometimes occur, whereas above 30 parts by weight thereof, no better formability can be obtained and such excessive addition is not economical.

In the case of a liquid lubricant according to the second aspect of the present invention, which comprises (a) a lubricating oil, (b) a phosphoric acid monoester represented by the general formula (1), and (c) at least one of fatty acid, fatty acid amide and metal soap, it is desirable to use 2 to 30 parts by weight of the phosphoric acid monoester and 1 to 20 parts by weight of at least one of fatty acid, fatty acid amide and metal soap per 100 parts by weight of the lubricating oil. Below 2 parts by weight of the phosphoric acid monoester and below 1 parts by weight of at least one of fatty acid, fatty acid amide and metal soap, a sufficient lubricating effect may not be sometimes obtained, whereas above 30 parts by weight of the former and above 20 parts by weight of the latter, no better

formability can be obtained, and such excessive addition is not economically advantageous.

In the case of the suspension and dispersion according to the present invention, an emmulsifying agent can be used, where it is desirable to use 0.1 to 5 parts by weight of the emulsifying agent per 100 parts by weight of the lubricating oil.

According to the most preferable mode of the present invention, a liquid lubricant comprises 100 parts by weight of a lubricating oil (viscosity: 50 - 200 mm^2/sec at 40°C), 1 to 30 parts by weight of a phosphoric acid monoester such as monobutyl phosphate, 1 to 10 parts by weight of fatty acid such as heptanoic acid, and 1 to 5 parts by weight of an emulsifying agent such as polybutenylsuccinic acid ester. The lubricating film obtained from this liquid lubricant has a thickness of 3 μm or less, which is considerably smaller than the thickness of the conventional phosphate coating film, e.g. about 10 μm, though the formability of the present lubricating film is equivalent or superior to that of the conventional one, and particularly a more smooth forming surface can be obtained.

The present liquid lubricant can be put into service only by wetting the surface of a metallic workpiece or a die for metal forming with the present liquid lubricant according to the well known method, for example, by spraying, brushing, dipping, etc., followed by metal forming, or can be also used by

heating either the present liquid lubricant or the metallic workpiece and dipping the metallic workpiece into the lubricant, thereby forming a lubricating film on the surface of metallic workpiece. For example, a metallic workpiece is dipped into the present liquid lubricant heated to at least 50°C for 0.5 - 10 minutes, for example, 100°C for 0.5 minutes, whereby a lubricating film having a lubricating effect equivalent or superior to that of the conventional phosphate coating film and a high rust-proof effect on the metallic workpiece can be very readily formed. Thus, the present invention can considerably shorten the lubricating film-forming process.

An antioxidant for preventing deterioration of the present liquid lubricant, a rust proof agent for preventing a metallic workpiece from rust, etc. can be added to the present liquid lubricant, so far as they are not in ranges to deteriorate the desired lubricating effect of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a side view of a workpiece used for evaluation of the properties of lubricants.

Fig. 2 is a vertical cross-sectional view of an extrusion die used for evaluation of the properties of lubricants.

Fig. 3 is a diagram showing relationship between the reduction of area or extrusion diameter and

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forming limit temperature (°C) according to Examples and Comparative Examples.

Fig. 4 is a diagram showing relationship between the content of fatty acid and the forming limit temperature (°C).

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The effects of the present liquid lubricant for metal forming will be described in detail below, referring to Examples, which will not be limitative to the present invevtion.

Examples 1 to 20

The present liquid lubricants having compositions shown in Table 1, where mineral oil (FBK150, trademark of a product made by Nippon Oil Company, Ltd., Japan) was used as a base oil, were applied to the surfaces of workpiece 2, as shown in Fig. 1, chromium-molybdenum steel columns with a nose, 9.9 mm in diameter, 30 mm long and 90° at nose angle [SCM 415 as described in JIS (Japanese Industrial Standard G 4105: C: 0.03 - 0.18 wt.%, Si: 0.15 - 0.35 wt.%, Mn: 0.60 - 0.85 wt.%, P: under 0.030 wt.%, S: under 0.030 wt.% Cr: 0.90 - 1.20 wt.%, Mo: 0.15 - 0.30 wt.%, the balance being Fe)].

Then, the workpieces 2 were subjected to metal forming by forward extrusion with an hard metal die 5 with an extrusion angle of 120° and an extrusion diameter of 5 mm (reduction of area: 75%) and a punch 1, as

shown in Fig. 2, to evaluate the formability. The results of evaluation are shown in Table 2.

The formability was evaluated as follows. A band heater 4 was provided around the die 5 to elevate the die temperature from the room temperature stagewise, for example, by 5 to 20°C for each stage, and 20 - 30 workpieces 2 of each Example, to which the present liquid lubricants were applied, were subjected to metal forming, and maximum formable temperatures up to which no galling developed on the surfaces of workpieces after the metal forming were measured.

A higher maximum formable temperature has a better formability of the lubricant.

Forming load at the maximum formable temperature is obtained by recording an extrusion pressure at the forming by a strain gage.

The conventional lubricants used for comparison with the present liquid lubricants are as follows:

Comparative Example 1

Commercially available oil for metal forming having the following composition was used:

Additive:	fatty oil content	116 parts by weight
	chlorine content	32 parts by weight
	sulfur content	16 parts by weight
Base oil:	mineral oil	100 parts by weight

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Comparative Example 2

Commercially available oil for metal forming similar to that of Comparative Example 1, which comprises a mixture of mineral oil and ester oil as a base oil, and fatty acid, oleic acid, and chlorinated hydrocarbon compound as additives was used.

Comparative Example 3

The same workpieces used in Examples 1 to 20 were treated according to the well known phosphate coating consisting of the following steps: defatting → water washing → acid pickling → water washing → phosphating → water washing → neutralization → metal soap lubricating treatment → drying.

Formabilities of the workpieces of Comparative Examples 1 to 3 were evaluated in the same manner as in Examples 1 to 20. The results of evaluation of Comparative Examples 1 and 2 are shown in Table 2.

As is evident from the results of Table 2, all of the present liquid lubricants had considerably improved formabilities, as compared with Comparative Examples. Forming loads were also smaller than that of Comparative Examples, and thus the coefficient of friction is low with a good lubricating effect.

Examples 21 - 41

The present liquid lubricants for metal forming were prepared by mixing polyol ester oil having a

viscosity of 56 mm^2/sec at 40°C with octanoic acid, heptanoic acid, octanamide and phosphoric acid monoester as shown in Table 3 by means of a high speed mixer.

The liquid lubricants were applied to workpieces of chromium-molybdenum steel and the formability and forming load of the lubricants were measured by means of the same die as used in Example 1. The results are shown in Table 4.

As is evident from the results of Table 4, the forming loads were smaller than those of Comparative Examples 1 and 2 shown in Table 2.

Examples 42 - 59

The present liquid lubricants for metal forming were parepared from compositions of mineral oil having a viscosity of 150 mm^2/sec at 40°C, fatty acid, fatty acid amide and metal soap shown in Table 5.

The lubricants were subjected to measurement of forming loads and formabilities under the same conditions as in Example 1. Results are shown in Table 6.

As is evident from Table 6, the forming loads were smaller and the formabilities were better than those of Comparative Examples shown in Table 2.

Examples 60 - 77

The present lubricants having the same compo-

sition and the same mixing ratio as in Table 5 except that polyol ester oil having a viscosity of 56 mm^2/sec at 40°C was used in place of the mineral oil was subjected to forming under the same conditions as in Example 1. The forming loads and formabilities are shown in Table 7.

As is evident from the results of Table 7, substantially equal results to those of Examples 42 - 59 were obtained.

Examples 78 - 88

The present liquid lubricants containing mineral oil having a viscosity of 56 mm^2/sec at 40°C (FBK-56, a product made by Nippon Oil Co., Ltd., Japan) and/or polyol ester oil having a viscosity of 56 mm^2/sec at 40°C, shown in Table 8, were used as a lubricating film-treating agent for a metallic workpiece. The same workpieces as used in Example 1 and heated to 100°C were dipped in the present liquid lubricants to make lubricating film treatment. Then, the forming loads and formabilities of the lubricating films were evaluated by means of the same die (or tool) as used in Example 1. The results of evaluation are shown in Table 9.

As is evident from Table 9, the formabilities of the lubricating films according to the present liquid lubricants are equivalent to that of the conventional phosphate film, and the forming loads of the present lubricating films are lower and the lubricating effects

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are better than those of the phosphate coating film.

In Fig. 3, a diagram showing relationship between the reduction of area (%) or extrusion diameter (mm) on the abscissa and the forming limit temperature (°C) on the ordinate according to typical Examples of the present invention and Comparative Example is given, where the reduction of area (%) is given by the following formula:

$$(D^2 - d^2)/D^2 \times 100 \ (\%)$$

D: diameter of workpiece before forming

d: drawing (or extrusion) diameter, i.e. diameter of workpiece after forming (mm)

As is evident from Fig. 3, the present liquid lubricants have better formabilities than the conventional one.

The formable limit temperatures were measured up to 280°C, but those which seem to have higher formable limit temperatures are indicated by the upward arrow mark ↑ on the curve. In Fig. 3, examples consisting only of mineral oil, of mineral oil and fatty acid and of mineral oil and metal soap are shown for comparison, which have considerably poor formabilities.

Example 89

The present liquid lubricants consisting of 100 parts by weight of mineral oil having a viscosity

of 150 mm^2/sec at 40°C, 1 - 30 parts by weight of monobutyl phosphate, 1 - 12 parts by weight of heptanoic acid, and 1 part by weight of polybutenylsuccinic acid ester as an emulsifying agent were prepared and their formabilities were evaluated in the same manner as in Example 1. The results are shown in Fig. 4. As is evident from Fig. 4, preferable ranges are 2 - 30 parts by weight of monobutyl phosphate and 1 - 10 parts by weight of heptanoic acid.

Table 1

Component (Parts by weight) / Example No.	Liquid lubricant composition of the invention																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Mineral oil	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Octanoic acid	6	6	6	6	6	6	6										1			
Heptanoic acid								6	6	6	6	6	6	6				1		
Octanamide															6	6				
Monomethyl phosphate	12							12							12		5		12	
Monoisopropyl phosphate		12							12											
Monobutyl phosphate			12							12						12		5		12
Monododecyl phosphate				12							12									
Monooctadecyl phosphate					12							12								
Monooleyl phosphate						12							12							
Monophenyl phosphate							12							12						

Table 2

Example No.	Forming load (kg/mm^2)	Formability (°C)
1	166.3	210
2	164.2	220
3	159.7	220
4	166.5	190
5	161.2	180
6	168.2	160
7	158.7	260
8	159.5	220
9	157.8	225
10	158.2	215
11	159.1	220
12	160.1	195
13	162.3	175
14	158.9	270
15	167.2	160
16	167.5	165
17	168.1	150
18	163.2	160
19	162.8	165
20	170.1	117
Comp. Ex. 1	180.5	30
" 2	208.5	30

Table 3

Component (Parts by weight) \ Example No.	Liquid lubricant composition of the invention																				
	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
Polyol ester oil	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Octanoic acid	6	6	6	6	6	6	6										1				
Heptanoic acid								6	6	6	6	6	6	6				1			
Octanamide															6	6					
Monomethyl phosphate	12							12							12		5		12		
Monoisopropyl phosphate		12							12												
Monobutyl phosphate			12							12						12		5		12	
Monododecyl phosphate				12							12										
Monooctadecyl phosphate					12							12									12
Monooleyl phosphate						12							12								
Monophenyl phosphate							12							12							

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Table 4

Example No.	Forming load (kg/mm2)	Formability (°C)
21	163.1	195
22	162.2	195
23	159.8	200
24	163.3	180
25	164.0	180
26	165.0	145
27	157.8	255
28	158.3	210
29	158.2	210
30	159.0	205
31	160.2	190
32	166.3	165
33	157.8	265
34	166.9	150
35	166.8	145
36	166.2	145
37	166.3	145
38	167.0	130
39	165.3	170
40	160.7	180
41	167.1	160

Table 5

Component (Parts by weight) \ Example No.	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59
	Liquid lubricant composition of the invention																	
Mineral oil	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Monobutyl phosphate	12	12	12	12	12	12	12	12	12	12	12	12	12	13	13	13	27	27
Butanoic acid	6													2.6	2.6	2.6		
Undecanoic acid		6															7	
Hexadecanoic acid			6															
Cis-9,cis-12-octadecadienic acid				6												2.6		
Cis-9-octadecenoic acid					6													
Pentanoic acid						6												
Hexanamide							6								2.6			
Myristylamide								6										7
Oleylamide									6									
Linolamide										6								
Lithium oleate											6			2.6				
Lithium stearate												6						
Nickel naphthenate													6					
Monooleyl phosphate														12	13	13		

Table 6

Example No.	Forming load (kg/mm^2)	Formability (°C)
42	156.2	225
43	158.1	220
44	158.5	220
45	158.2	210
46	158.0	215
47	157.8	215
48	158.1	210
49	158.3	200
50	159.2	200
51	159.4	200
52	160.1	180
53	161.0	180
54	160.5	185
55	159.0	210
56	159.0	210
57	159.2	200
58	158.8	210
59	159.9	190

Table 7

Example No.	Forming load (kg/mm^2)	Formability (°C)
60	158.8	220
61	158.1	220
62	159.5	215
63	158.0	210
64	157.9	215
65	159.8	210
66	158.0	210
67	159.7	195
68	158.9	200
69	158.0	210
70	160.1	185
71	160.3	180
72	160.2	185
73	159.0	215
74	158.3	210
75	158.5	200
76	158.7	205
77	158.4	200

Table 8

Example No. / Component (Parts by weight)	Liquid lubricant composition of the invention										
	78	79	80	81	82	83	84	85	86	87	88
Mineral oil	100	100	100	100	100				100		100
Polyol ester oil						100	100	100		100	88
Monomethyl phosphate	12	12	12	12					5		10
Monobutyl phosphate					12	12	12	12		5	
Butanoic acid	6				6				1	1	
Cis-9-octadecenoic acid		6				6					
Sodium stearate			6				6				2
Oleylamide				6				6			

Table 9

	Example No.											Comp.* Ex. 3
	78	79	80	81	82	83	84	85	86	87	88	
Forming load (kg/mm^2)	188	182	183	180	187	185	182	180	183	188	182	225
Formability (°C)	>280	>280	>280	>280	>280	>280	>280	>280	>280	280	280	>280

* Phosphate coating film

As is obvious from the foregoing, the present liquid lubricant for metal forming can form a dense and heat-resistant lubricating film on the frictional surface of a workpiece or die by virtue of the heat generated during the forming owing to a synergistic effect of phosphoric acid monoester and fatty acid or aliphatic acid amide or metal soap as added to lubricating oil, and thus can be used in forming of parts with higher reduction of area or articles with more complicated shape than the conventional lubricant for the forming.

The lubricating film formed by dipping a heated workpiece into the present liquid lubricant or by dipping a workpiece into the heated liquid lubricant of the present invention has a formability equivalent to that obtained by phosphate film treatment. Furthermore, only one run of film treatment is enough in the present invention, and thus the present invention can greatly contribute to simplification of the process and cost reduction.

WHAT IS CLAIMED IS:

1. A substantially water-free, liquid lubricant for metal forming, which comprises (a) a lubricating oil, and (b) at least one phosphoric acid monoester from the group represented by the general formula:

$$RO-\overset{\overset{\displaystyle O}{\|}}{P}-(OH)_2$$

wherein R is alkyl, alkylalkenyl or aryl.

2. A substantially water-free liquid lubricant according to Claim 1, wherein the lubricating oil is a mineral oil, or a synthetic oil, or a mixture thereof.

3. A substantially water-free liquid lubricant according to Claim 1 or 2, wherein the phosphoric acid monoester is at least one of monomethyl phosphate, monoisopropyl phosphate, monobutyl phosphate, monooctyl phosphate, monoisodecyl phosphate, monododecyl phosphate, monotridecyl phosphate, monooctadecyl phosphate, monooleyl phosphate, and monophenyl phosphate.

4. A substantially water-free, liquid lubricant according to any of claims 1 to 3, wherein at least 2 parts by weight of the phosphoric acid monoester are contained per 100 parts by weight of the lubricating oil.

5. A substantially water-free, liquid lubricant according to any of claims 1 to 4, further containing at least one member of the group comprising fatty acids, fatty acid amides and metal soaps.

6. A substantially water-free, liquid lubricant according to Claim 5, wherein at least 2 parts by weight of the phosphoric acid monoester and at least one part by weight of the fatty acids, the fatty acid amides and the metal soaps are contained per 100 parts by weight of the lubricating oil.

7. A substantially water-free liquid lubricant according to any of claims 1 to 6, further containing an emulsifying agent.

8. A substantially water-free, liquid lubricant according to Claim 7, wherein 0.5 to 5 parts by weight of the emulsifying agent are contained per 100 parts by weight of the lubricating oil.

9. A substantially water-free, liquid lubricant for metal forming, which comprises (a) 100 parts by weight of a lubricating oil having a viscosity of 50 to 200 mm^2/sec at 40°C, (b) 2 to 30 parts by weight of at least one phosphoric acid monoester from the group represented by the general formula:

$$RO-\overset{\overset{\displaystyle O}{\|}}{P}-(OH)_2$$

wherein R is alkyl, alkylalkenyl or aryl, (c) 1 to 10 parts by weight of at least one member of the group comprising fatty acids, fatty acid amides and metal soaps, and (d) 1 to 5 parts by weight of an emulsifying agent.

10. A process for metal forming which comprises applying a lubricant for metal forming to the surface of a metallic workpiece (2) to be formed or the surface of a die (5) or both, and forming a lubricating film on the surface by virtue of least generated during the forming, wherein the lubricant is a substantially water-free, liquid lubricant according to any of Claims 1 to 9.

11. A process according to Claim 10, wherein the liquid lubricant is applied to the surface after heating at least one of the metallic workpiece (2), the die (5) and the liquid lubricant, and then the metal forming is carried out.

12. A process according to Claim 11, wherein the liquid lubricant heated at least at 50°C is applied for at least 0.5 minutes.

FIG. 1

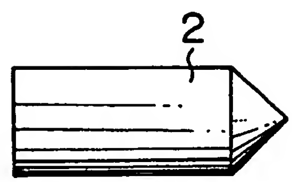


FIG. 2

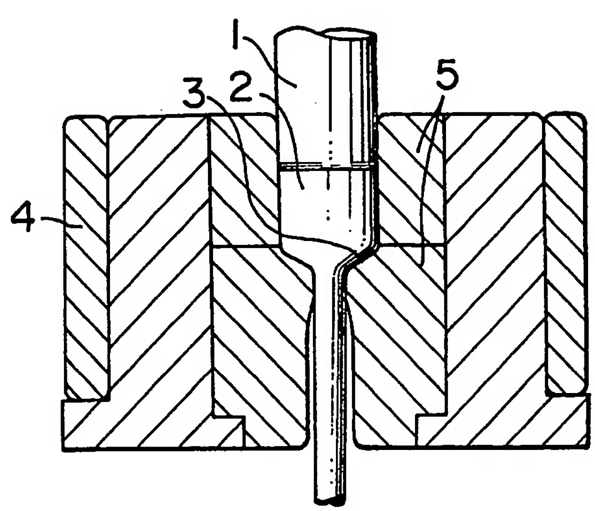


FIG. 3

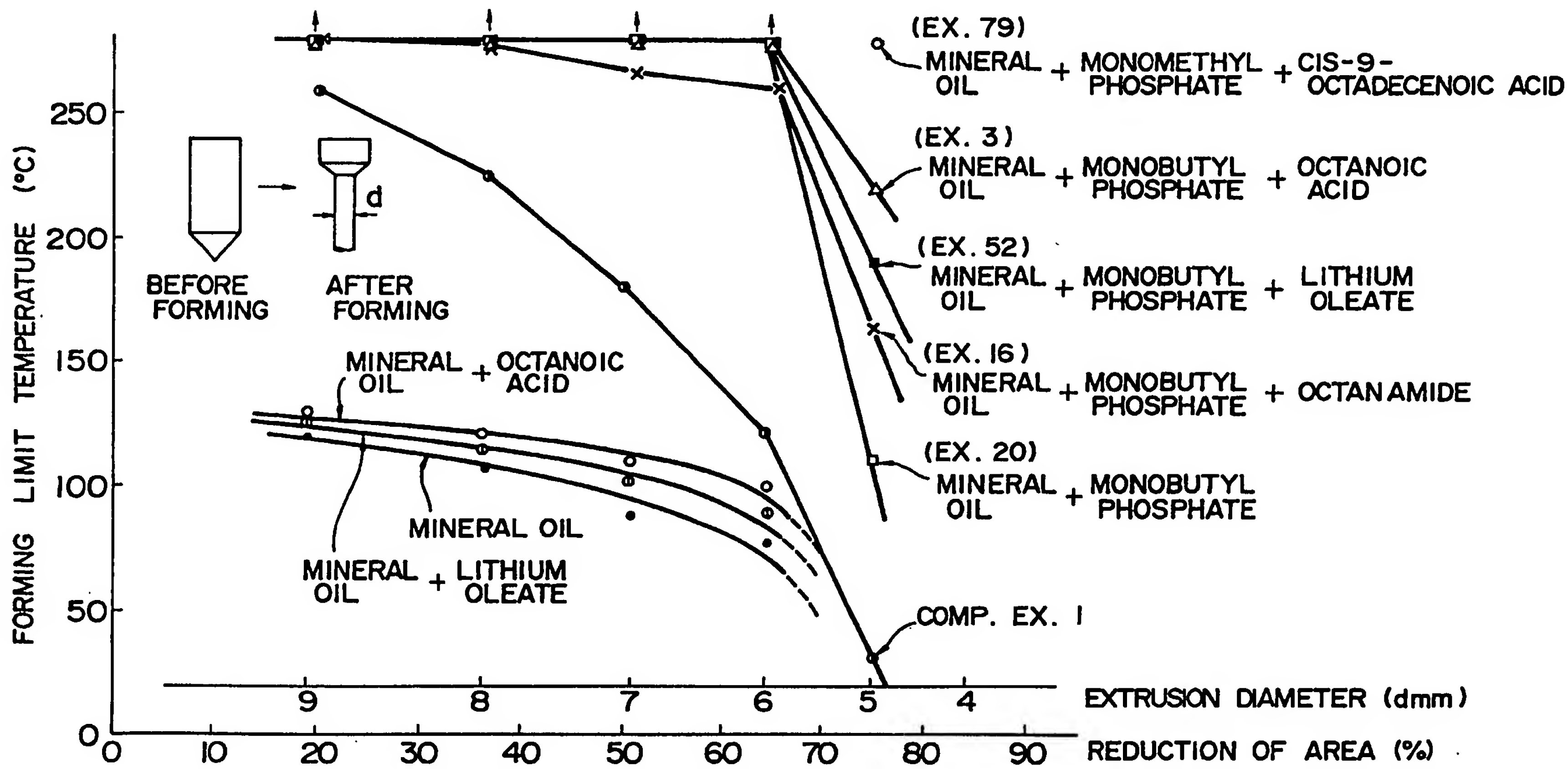
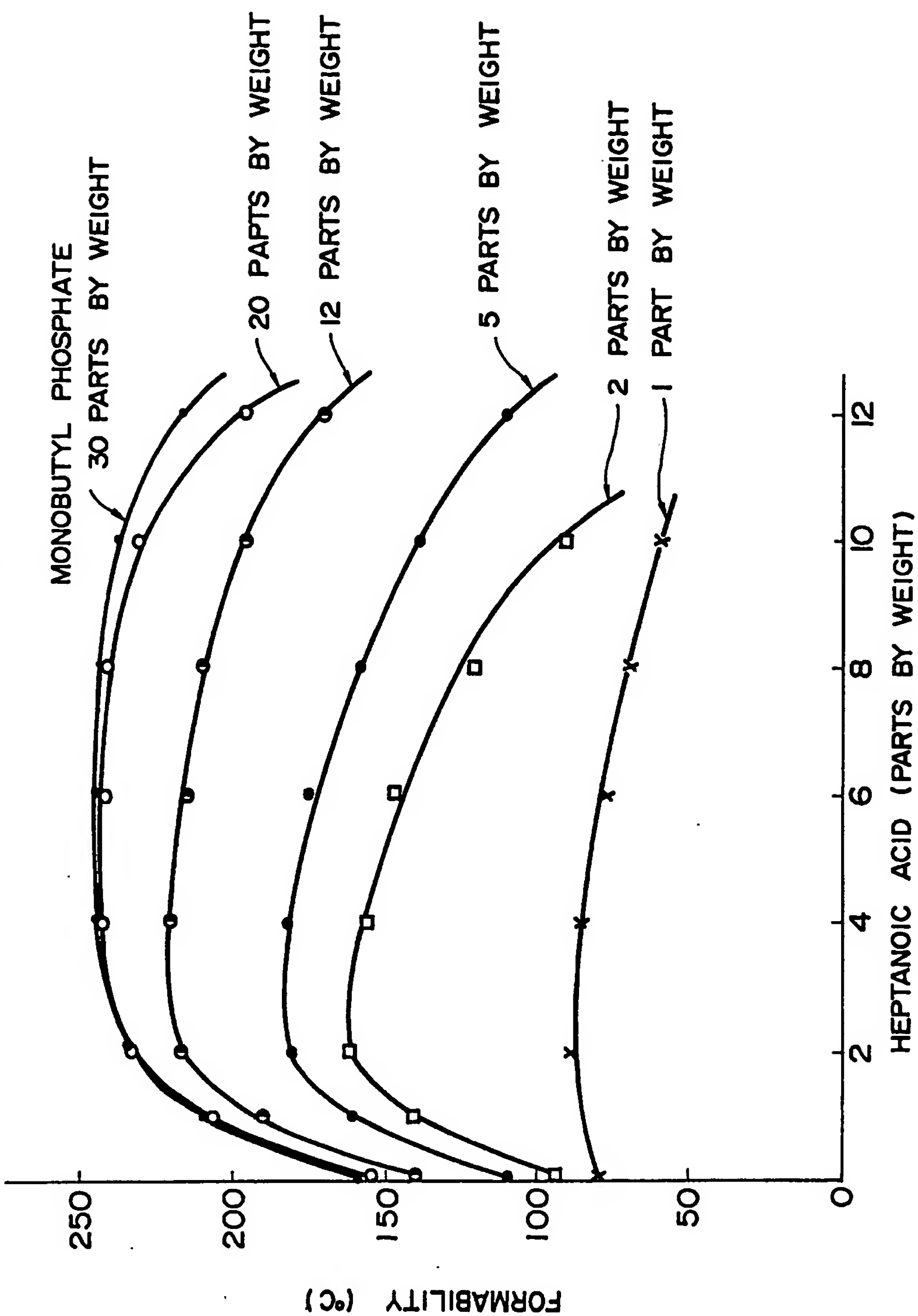

(EX. 79) MINERAL OIL + MONOMETHYL PHOSPHATE + CIS-9-OCTADECENOIC ACID
(EX. 3) MINERAL OIL + MONOBUTYL PHOSPHATE + OCTANOIC ACID
(EX. 52) MINERAL OIL + MONOBUTYL PHOSPHATE + LITHIUM OLEATE
(EX. 16) MINERAL OIL + MONOBUTYL PHOSPHATE + OCTANAMIDE
(EX. 20) MINERAL OIL + MONOBUTYL PHOSPHATE
COMP. EX. I
BEFORE FORMING
AFTER FORMING
d
MINERAL OIL + OCTANOIC ACID
MINERAL OIL
MINERAL OIL + LITHIUM OLEATE
FORMING LIMIT TEMPERATURE (°C)
250
200
150
100
50
0
9
8
7
6
5
4
EXTRUSION DIAMETER (dmm)
0
10
20
30
40
50
60
70
80
90
REDUCTION OF AREA (%)

FIG. 4


MONOBUTYL PHOSPHATE
30 PARTS BY WEIGHT
20 PAPTS BY WEIGHT
12 PARTS BY WEIGHT
5 PARTS BY WEIGHT
2 PARTS BY WEIGHT
1 PART BY WEIGHT
FORMABILITY (°C)
250
200
150
100
50
0
2
4
6
8
10
12
HEPTANOIC ACID (PARTS BY WEIGHT)